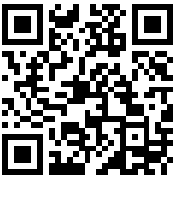

U. S. DEPARTMENT OF AGRICULTURE
FARMERS' BULLETIN No. 1607

THE NEMATODE DISEASE OF WHEAT AND RYE

THE NEMATODE DISEASE of wheat and rye occurs in six States (Maryland, Virginia, West Virginia, North Carolina, South Carolina, and Georgia) and is gradually spreading. It may be present in many localities where it has not yet been recognized.

The disease may be recognized in threshed grain by the presence of hard galls, which often are mistaken for weed seeds or other impurities. These galls contain the nematodes (tiny worms) which attack wheat, rye, emmer, and spelt.

The nematode galls may be carried for great distances in seed grain or in baled straw. Threshing machines may spread them from farm to farm.

The nematodes do not live more than one year in the soil in the absence of crops of wheat, rye, emmer, or spelt.

The disease is readily controlled by sowing only uninfested seed on uninfested land.

This bulletin supersedes Farmers' Bulletin 1041, The Eelworm Disease of Wheat and Its Control.

Washington, D. C. Issued November, 1929

THE NEMATODE DISEASE OF WHEAT AND RYE

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CONTENTS

INTRODUCTION

THE NEMATODE DISEASE of wheat and rye is caused by the nematode or eelworm, a very tiny worm technically known as *Tylenchus tritici* (Steinbuch) Bastian. It is slowly spreading in the wheat-growing areas in the southeastern United States. A number of reports of infestation have been received from districts hitherto thought to be free from the disease. It seems desirable, therefore, to bring to the attention of those interested the main facts concerning the disease, particularly the description, cause, grains attacked, geographic distribution, manner of spread, losses, and control measures. It is hoped that this information will be of assistance in recognizing and eradicating the disease where it now occurs and in thus preventing its further spread.

DESCRIPTION OF THE DISEASE

GALLS IN GRAIN

The presence of the nematode disease in wheat usually is discovered by finding the hard dark galls in the threshed grain. These galls often are mistaken for cockle seeds, vetch seeds, smut balls, bin-burnt kernels, ergot bodies, or other substances commonly found in threshed grain. (Fig. 1.) But cockle seeds are easily distinguished by their spiny coat and characteristic shape, vetch seeds by their smoothness, uniform color, and roundness, smut balls by their black, dusty contents, fishy odor, and the ease with which they can be crushed between the fingers, and bin-burnt kernels and ergot bodies by their general shape and cross section. Some of these differences are illustrated in Figure 1.

The nematode galls from wheat are from one-eighth to three-sixteenths of an inch in length and from one-sixteenth to one-eighth

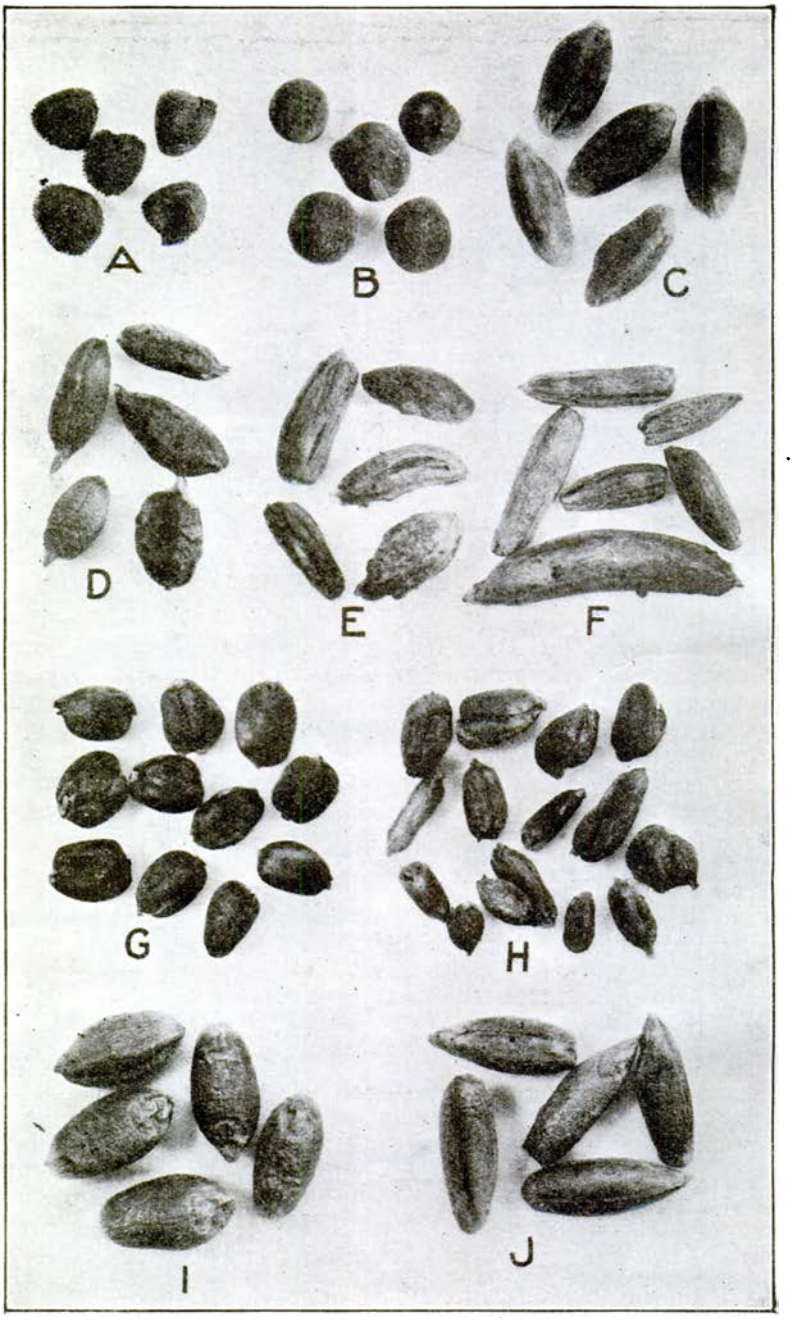

FIGURE 1.—Comparison of nematode galls from wheat and rye with normal kernels of wheat and rye and with impurities commonly found in threshed grain. (Enlarged three times.) Note the comparative uniformity in the size and form of the galls from wheat and the variation in the size and form of the galls from rye. A, Cockle seed; B, vetch seed; C, bin-burnt wheat kernels; D, bunt balls; E, ergot sclerotia from wheat; F, ergot sclerotia from rye; G, nematode galls from wheat; H, nematode galls from rye; I, wheat kernels; J, rye kernels

of an inch in width, on the average. They are rather dark in color, with light-brown tips, and usually are grooved somewhat like a wheat kernel. Many galls vary from the average in size and shape, so that sometimes it is difficult to recognize them. Galls from emmer and spelt are identical in size, color, and shape with those from wheat, but galls from rye, as a rule, are smaller, relatively longer,

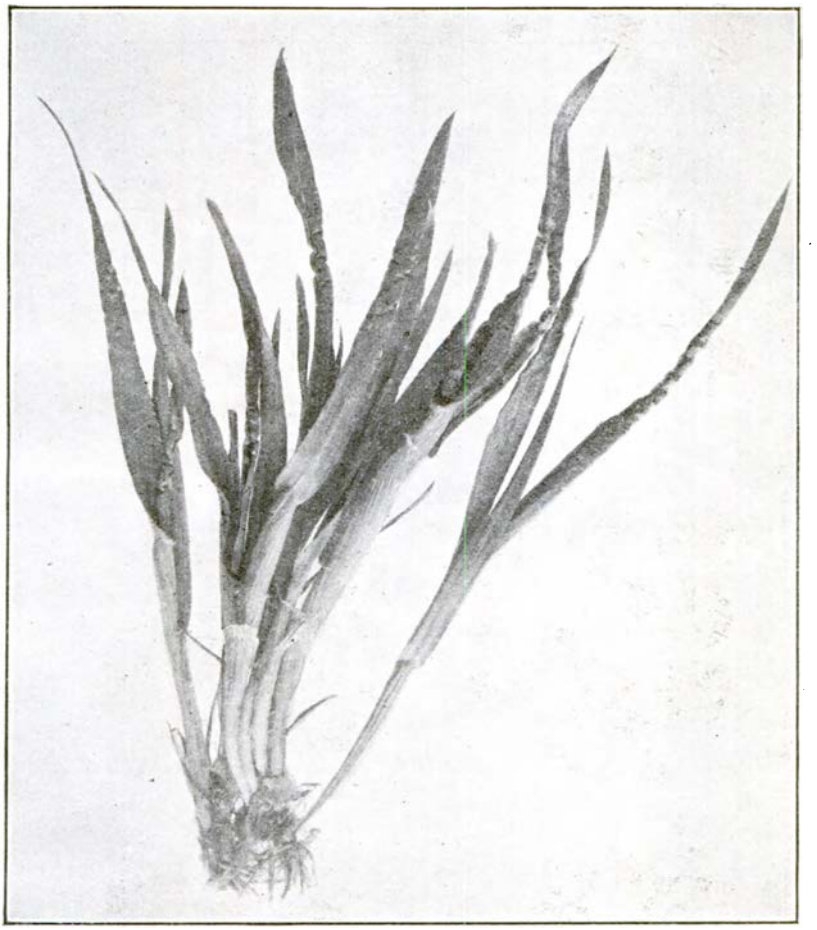

FIGURE 2.—Wheat seedlings attacked by nematodes. Note the wrinkled leaves with curled edges and the emerging leaves tightly rolled

and lighter in color. Galls from certain varieties of spring wheat also are slightly different in shape and color.

SEEDLING SYMPTOMS

If seed containing nematode galls is sown, or if clean seed is sown on soil infested from a previously diseased crop, many of the seedlings will show the rolling, twisting, curling, or wrinkling of the leaves and other plant distortions characteristic of the disease. (Fig. 2.) The rolling or curling of a leaf often cramps the next

emerging leaf, causing it to become badly distorted, as is shown in Figure 3. The stem often is enlarged near the base; frequently it is bent, and usually it is more or less stunted. In some plants only one or two culms may be affected, while in others all or nearly all may be diseased.

As the plant approaches maturity the earlier symptoms become less evident unless the culm is very severely diseased, in which case

FIGURE 3.—Wheat seedling attacked by nematodes. Note the emerging leaf tightly held by the curling of the older leaf inclosing it

it either dies before heading or bears a very imperfect and badly diseased head.

HEAD SYMPTOMS

Diseased heads usually are shorter and thicker than the healthy ones, and the glumes are spread farther apart by the nematode galls, which replace the kernels. (Fig. 4.) Frequently several galls are found in place of a single kernel. (Fig. 5.) At first these galls

are shining and of a green color, but as the heads ripen, the galls turn dark brown or black in wheat, and straw colored in rye. Some heads contain only galls, while others contain both galls and kernels. It is not uncommon to find a single gall in an otherwise healthy head or a single sound kernel in a badly diseased head. Partially dis-

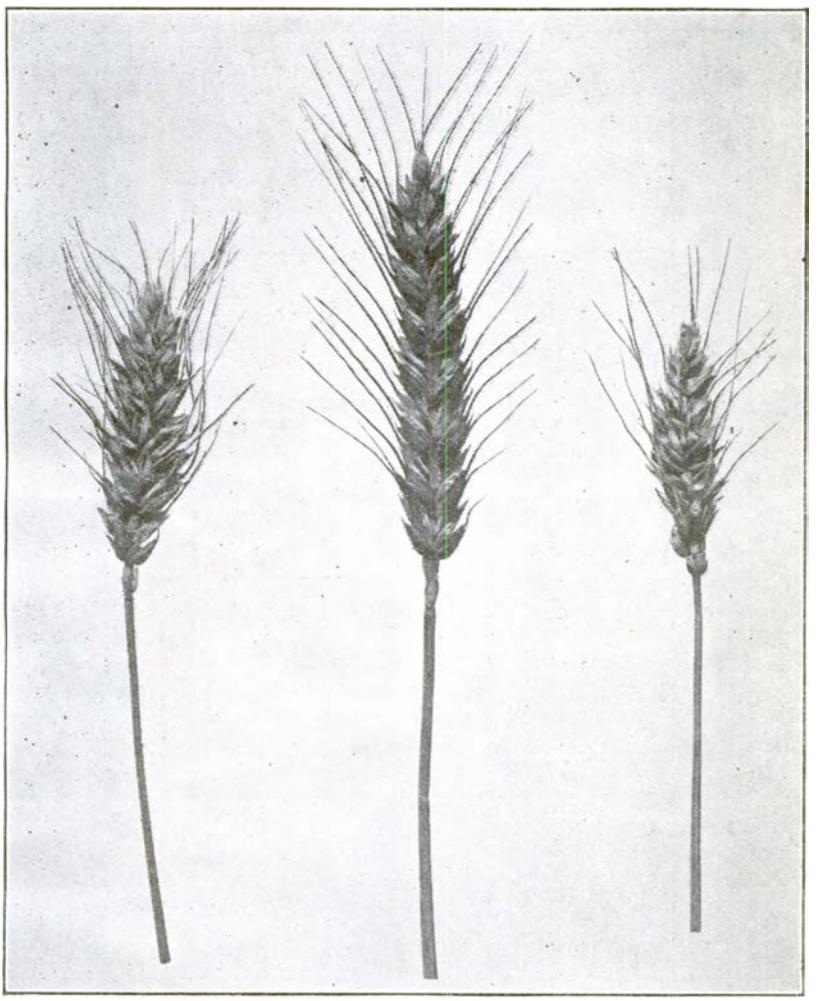

FIGURE 4.—Healthy head of wheat shown between two nematode-infected heads. In the diseased heads note the spreading chaff, the distorted awns, and the dark galls in place of normal wheat kernels. (About three-fourths natural size)

eased heads often are hard to distinguish from healthy heads. Diseased heads remain green longer than healthy ones, and at maturity the glumes often assume a dirty brownish color. The galls shatter out of the heads more readily than the kernels, and during harvest many galls fall to the ground, thus infesting the soil for a subsequent crop.

CAUSE OF THE DISEASE

The galls in the infested grain contain thousands of microscopic eellike worms called nematodes. A section much enlarged through a gall is shown in Figure 6. While inside of the dry gall these nematodes or eelworms are in a dried-out dormant mass, but if the gall is

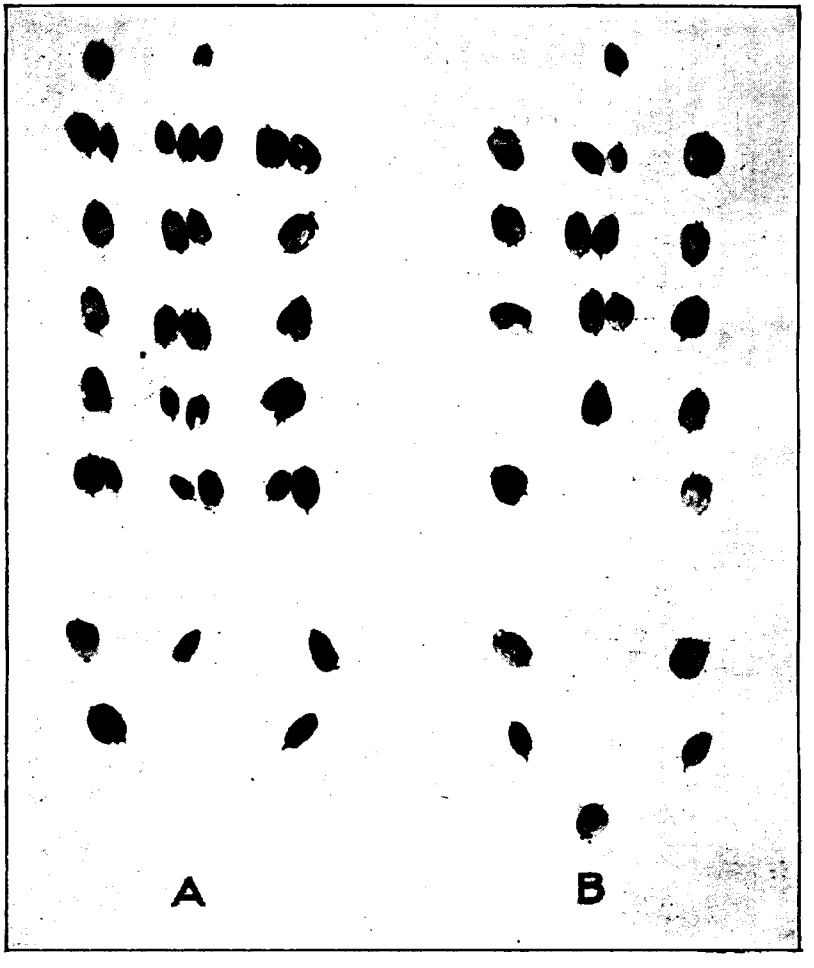

FIGURE 5.—Nematode galls from a head of Dietz wheat arranged as found in the different flowers of the spikelets (meshes or breasts). A and B, Galls from spikelets on the opposite sides of the same head

opened and the nematodes are placed in water they absorb moisture and become eellike in appearance, as shown in Figure 7. In a short time they start an active whipping movement.

When nematode galls are sown with the seed, or have dropped to the ground from a previously diseased crop, the walls of the galls are softened by water and soon collapse, allowing the nematodes to escape into the soil. They get in between the leaf sheaths of the

young wheat or rye seedlings and finally reach the growing point, where, without effort on their part, they are carried up by the elongation of the growing stem. They remain about the growing points until the grain heads begin to form. Then they attack the young developing heads and cause the formation of galls instead of normal flower parts. Within these newly formed galls the nematodes grow to be mature adults, male and female. They copulate, and the females lay eggs, after which the adults of both sexes die. The eggs hatch into young nematodes, which, at the maturity of the plant, go into the dried dormant state mentioned above. In this condition they have been found to remain alive for as long as nine years. If the

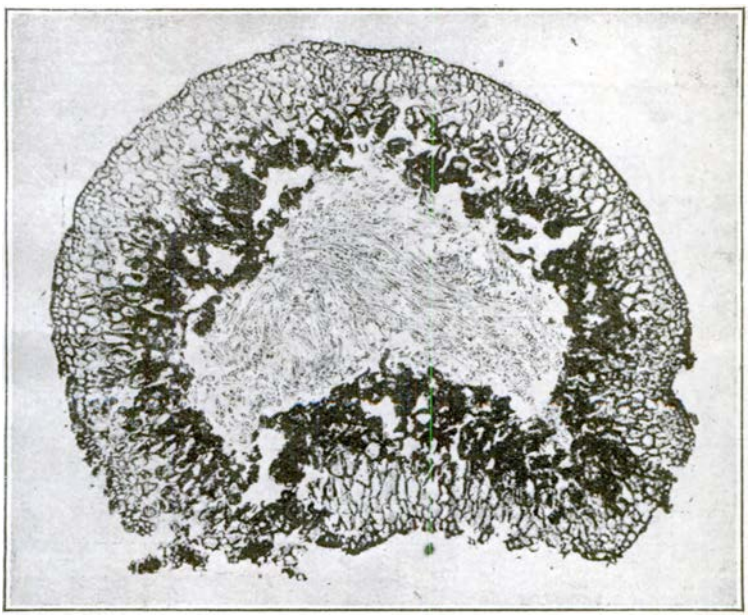

FIGURE 6.—Cross section of a nematode gall magnified 35 times, showing the thick wall surrounding the white mass of dormant nematodes in the center. When placed in moist soil the wall of the gall soon softens and the nematodes, revived by the absorption of water, escape from the gall into the soil where they attack the young wheat or rye seedlings

galls were stored under conditions especially favorable for the nematodes, the latter might remain alive even longer.

GRAINS ATTACKED

The nematode disease was originally discovered on wheat, but it also readily attacks rye, emmer, and spelt. Oats are attacked to some extent in the seedling stage, but in no case have mature galls been found on this crop. Barley may be classed as practically immune, although in one case a few small, imperfect galls were found in the heads of Hansee Hull-less barley, the seed of which had been heavily inoculated with nematode galls. Grasses, other than cereals, are not attacked, so far as known.

GEOGRAPHIC DISTRIBUTION

The nematode disease of wheat and rye is known to occur on every continent. The greatest losses have been reported from the countries of central Europe. In the United States it is known to occur at present in Maryland, Virginia, West Virginia, North Carolina, South Carolina, and Georgia. In 1909 it was reported also from California and New York, but since that time it has not been found in either of those States. It possibly may occur in other States where, up to the present, it may have been overlooked or mistaken for something else. In Wilkes County, N. C., the introduction of the disease was traced to shipments of seed wheat from Virginia. Therefore, it seems highly probable that shipments of infested seed may have carried the disease into other States from which it has not yet been reported.

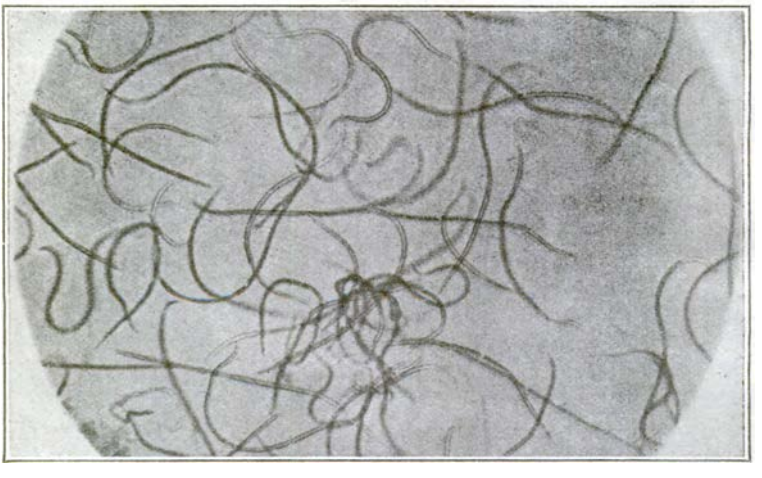

FIGURE 7.—Nematodes taken from a gall, placed in water, and photographed through a microscope which magnifies them about 30 times. In water the nematodes move actively with an eellike motion; therefore they are often called eelworms

Samples of plants thought to be affected with this disease, or of threshed grain thought to contain galls, should be sent for positive identification to the State agricultural experiment station or to the Office of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C.

HOW THE DISEASE SPREADS

The chief and only important method of spreading the disease to any distance is by means of the galls in the seed grain. Straw from an infected crop also may spread the pest to distant fields, as many of the galls are blown into the straw at threshing time.

Within a given locality, the threshing machine often spreads the disease from one farm to another. This was shown to be true in one locality in particular where the disease was known to occur for years only on farms in a certain threshing ring.

In marketing grain, in the infested regions, the screenings removed from the wheat at the mill or elevator usually are taken back to the farm, where they are fed to stock. Experiments have shown that the disease is not spread to the fields by the manure of farm animals which have eaten galls, but by the uneaten galls in the litter. An example of this is shown in Figure 8. In this case chickens were fed screenings containing a high percentage of nematode galls. As chickens do not relish these galls, most of the galls remained uneaten and were later gathered up with the litter and spread by means of a manure spreader on a strip of land in a field which was later sown to winter wheat. In the spring it was observed that most of the wheat in this strip apparently had winterkilled. The few plants that survived were badly diseased and produced only galls in the heads.

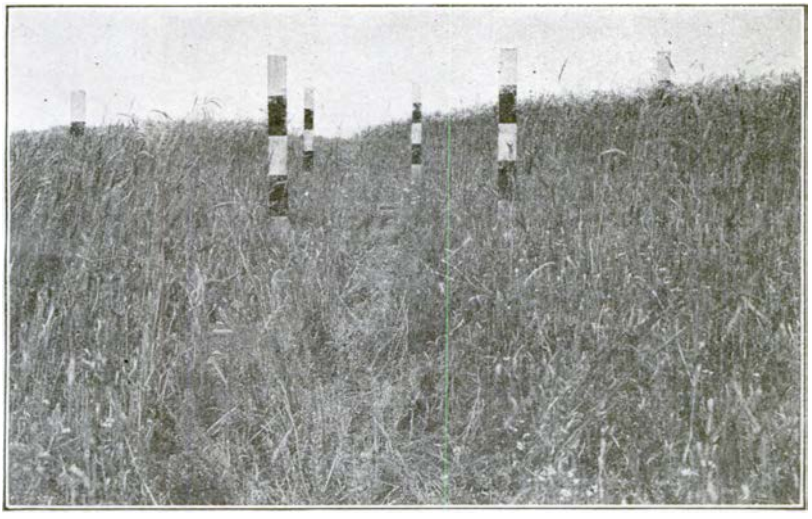

FIGURE 8.—A portion of a field of winter wheat showing where manure, badly infested with nematode galls in the litter, had been applied before sowing. All six stakes, similarly marked, were driven so that each projected 5 feet above the ground. In the center, where the infestation was most severe, the plants were either killed or badly stunted, as shown by the center stakes, 4 feet of which are visible, as compared with the outer stakes, which are almost hidden by the tall, healthy grain

Experiments have shown that, in the soil, the nematodes can travel by their own efforts only about 15 inches. Therefore, wheat or rye can be grown safely on clean soil fairly close to infested soil if cross cultivation is not practiced. However, heavy rains may wash some of the infested soil on to the near-by clean land and thus spread the nematodes. The nematodes can travel upward about a foot, so that deep plowing will not entirely eradicate the pest on infested land.

LOSSES DUE TO THE DISEASE

As the occurrence of the disease in the United States, so far as is known at present, is limited to six States, the loss it causes in wheat and rye, in the country as a whole, is relatively small. Nevertheless its possibilities are considerable, and therefore every precaution should be taken to prevent its spread.

Losses to individual farmers often are very severe. Estimates of losses on individual farms vary from a negligible amount to as high as 70 per cent of the crop. It is difficult to determine accurately the total damage in the ripe or threshed grain, because much of the injury is done in the seedling stage. Furthermore, many galls are blown out into the straw and screenings at threshing time. The most accurate way to determine the approximate loss in an infested field is to compare the yield per acre with that of a near-by uninfested field sown with the same seed, but uninfested, and under similar conditions of soil, fertility, drainage, etc. In this manner it has been found that, for two successive years, yields of infested rye were reduced 35 to 65 per cent, and yields of infested wheat were reduced 20 to 50 per cent, as compared with yields from the uninfested check plots. Spring wheat from infested seed yielded practically no grain, as almost every plant was badly infected and most of the heads contained only galls. From this experimental evidence it is safe to assume that the nematode disease would prove extremely destructive in a spring-wheat area.

CONTROL OF THE DISEASE

The nematode disease of wheat and rye may be readily controlled by using only clean seed and sowing it on uninfested land. No satisfactory resistant varieties of wheat or rye are known.

CLEAN SEED ON CLEAN SOIL

CLEAN SEED

Care should be taken to sow only adapted varieties of wheat or rye, free from nematode galls. If uninfested seed can not be obtained, or if it is desired to sow a particularly valuable lot of seed which is infested, the galls may be separated from the grain by floating them out in salt brine, or the nematodes in seed wheat may be killed by the modified hot-water treatment used for the control of loose smut.

The salt-brine method is as follows: Dissolve common salt in water at the rate of 40 pounds of salt to 25 gallons of water. A barrel or a small tank can be used for this purpose. After careful cleaning, pour the infested seed slowly into the salt solution, not more than a peck at a time, stirring vigorously at the same time. The nematode galls, light, worthless kernels, and trash will rise to the surface and float, while the sound kernels will sink. The former may be skimmed off with a strainer and disposed of as described later.

Some galls will be carried to the bottom with the grain. It should be stirred thoroughly and repeatedly, therefore, to give these galls a chance to rise to the surface. The salt brine, which can be used repeatedly, should be drained off and the grain thoroughly rinsed in fresh water. The rinsing in water must be thorough, as the salt will injure germination. After washing in water, the grain should be spread out on a floor or on canvas to dry. It should be stirred occasionally to hasten drying. After the grain is dry enough it may be sown at once or it may be more thoroughly dried and stored.

The skimmed-off material should be disposed of so that there will be no possibility of spreading the galls to land that is to be sown to wheat or rye that year. The safest method is first to rinse the skimmed-off material in water to remove the salt and then to plunge it into boiling water for a few minutes to kill the nematodes in the galls. After such treatment the material may be fed safely to chickens, hogs, or other stock, or thrown away.

The modified hot-water treatment as used for the control of the loose smut of wheat also kills the nematodes in the galls. This treatment consists of soaking the grain in water at ordinary temperatures for four to six hours and then in hot water at 129° F. for 10 minutes.

Where the disease occurs in the neighborhood, it is important to prevent its spread from farm to farm by means of the threshing machine. A threshing machine coming from an infested farm should be thoroughly cleaned, and the first lot of wheat or rye threshed should not be used for seed, as it is likely to contain nematode galls from the machine. Furthermore, it is advisable to thresh oats, barley, or some other crop before the wheat and rye.

CLEAN SOIL

Uninfested seed having been obtained, the next essential is to sow it on uninfested soil. Land which has just produced a crop of infested grain should be used for other crops for at least one year. Extensive field experiments have shown that the absence of wheat and rye, the susceptible grain crops, from the land for one year is sufficient to starve the nematodes in the soil. Clean wheat and rye may then be sown with safety on such land. Oats and barley are practically immune from attack and may be used in the rotation following wheat. In fact, any crop except wheat, rye, emmer, or spelt may be sown with safety so far as nematode injury is concerned.

Infested straw or infested manure and litter should not be put on land that is to be sown to wheat or rye unless it has been thoroughly rotted. The same holds true of stable manure from animals that have been bedded with straw from diseased grain. Experiments have shown that very few, if any, nematodes survive either passage through the alimentary tract of farm animals or prolonged decay in a manure pile.

RESISTANT VARIETIES

Numerous wheat varieties have been tested for resistance to the nematode disease, and only one variety, Kanred, has shown any appreciable degree of resistance. This variety, a hard red winter wheat, is not adapted to the southeastern United States.

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